TIME SERIES ANALYSIS OF TOTAL SUSPENDED SOLID (TSS) USING LANDSAT DATA IN BERAU COASTAL AREA, INDONESIA

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Abstract. Water quality information is usually used for the first examination of the pollution. One of the parameters of water quality is Total Suspended Solid (TSS), which describes the amount of matter of particles suspended in the water. TSS information is also used as initial information about waters condition of a region. TSS could be derive from Landsat data with several combinations of spectral channels to evaluate the condition of the observation area for both the waters and the surrounding land. The study aimed to evaluate Berau waters condition in Kalimantan, Indonesia, by utilizing TSS dynamics extracted from Landsat data. Validated TSS extraction algorithm was obtained by choosing the best correlation between field data and image data. Sixty pairs of points had been used to build validated TSS algorithms for the Berau Coastal area. The algorithm was TSS = 3.3238 * exp (34 099 * Red Band Reflectance). The data used for this study were Landsat 5 TM, Landsat 7 ETM and Landsat 8 data acquisition in 1994, 1996, 1998, 2002, 2004, 2006, 2008 and 2013. For detailed evaluation, 20 regions were created along the watershed up to the coast. The results showed the fluctuation of TSS values in each selected region. TSS value increased if there was a change of any kind of land cover/land used into bareland, ponds, settlements or shrubs. Conversely, TSS value decreased if there was a wide increase of mangrove area or its position was very closed to the ocean.

Keywords: *TSS, Landsat 5 TM, Landsat 7 ETM +, Landsat 8, watershed, mangrove*

1 INTRODUCTION

Utilization of remote sensing data for monitoring condition of environmental was done by making validated algorithms using field data measured directly in the field. The related research with extraction of TSS information has made great progress over the past decade. Some activities focus on developing an appropriate algorithms for the study area (Ruddik 2008).

There was the correlation between the number of particles and the optical properties in various variations of the function of the particle size studied (Babin 2003). The algorithm generated from the combination of field data with satellite data from ocean color has been validated so it could be applied (Petus 2010). The application of that algorithm could be used to monitor suspended particles found in both coastal and ocean.

The development of TSS information extraction model for Berau waters was conducted by finding correlation between TSS data measured in the field with image refelectance (Parwati 2006). The model itself was adopted from a model developed in the Mahakam Delta (Budhiman 2004). Several other models have been tested for the Berau waters, but the model developed in the Mahakam Delta showed the highest correlation between satellite and the field data. The algorithm for the extraction of TSS information using the Remote Sensing Data in Berau waters had been validated with field data. This study, were used timeseries satellite data including Landsat TM5 and ETM7 image data acquisition in 1994, 1998, 2002, 2004, 2006 and 2008 (Parwati 2008).

In complex water, the qualitative approach of suspected particle suspension could be applied on by using an algorithm that had been developed in other waters area. However the algorithm still need to be validated with field data (Long 2013).

Since 2003 the Landsat 7 ETM data have an error in its optical sensor, this study used another Landsat satellite which have same specification such as Landsat 8 (LDCM) for monitoring the water quality. Landsat Data Continuity Mission (LDCM) satellite had launched on February 11, 2013, NASA and its began providing open access image products from May 30, 2013. This satellite is known as Landsat 8 and designed to improve Landsat 7 satelitte data. Landsat 8 have more channels than Landsat 7 but the same in spatial resolution. Landsat 8 have eleven optical channels and two thermal channels.

The application of Landsat 8 data was very possible for further monitoring an enviromental condition of the region of a study area (Parwati 2010, Roy 2014). Some published papers used Landsat 8 satellite data for the evaluation of environmental quality have been widely practiced. One of them is conducted by Vanhelmont 2014, which study the extraction of water for TSS, Chl-a and CDOM parameters.

The feasibility analysis of the algorithm for the information extraction of TSS information using Landsat 8 satellite image data for Berau waters has been presented at the LAPAN Remote Sensing Seminar held in 2014 (Parwati 2014). The test of validated algorithm was conducted using Landsat 8 data acquisition in 2013. The study area were divided into 25 regions, where each region represented the dynamic conditions of various activities on the upper land. Thus, the availability of Landsat remote sensing data become the main requirement due to the monitoring of waters condition is needed, continously.

The objective of this study was to evaluate the condition of Berau waters along watershed until coastal area. Landsat times series data with TSS and Land use extraction information were used for that evaluation.

2 MATERIALS AND METHODOLOGY

2.1 Time and Location

Research activities was carried out in 2014 after Landsat 8 data was successfully received. The research location was taken along the watershed to the coastal of Berau area, East Kalimantan.

2.2 Data and Equipment

The data used in this research were presented in Table 2-1. The image processing and analysis are used some software such as ER Mapper software, Arc Info, Arc View and Microsoft Excel.

Table 2-1. Landsat Data Used

No	Data	Acquisition Date
1	Landsat 5 TM	July 10, 1994
2	Landsat 5 TM	June 21, 1996
3	Landsat 5 TM	August 4, 1998
4	Landsat 7 ETM	July 8, 2002
5	Landsat 7 ETM	June 6, 2004
6	Landsat 5 TM	August 12, 2006
7	Landsat 5 TM	June 3, 2008
8	Landsat 8	July 14, 2013

2.3 Data Analysis

The validation of the TSS information extraction algorithm was done empirically by comparing TSS data measured in the field with the reflectance image data. The total of 60 sample points were taken in the field, with the location position were along the watershed to the Berau coastal shown in Figure 2-1.

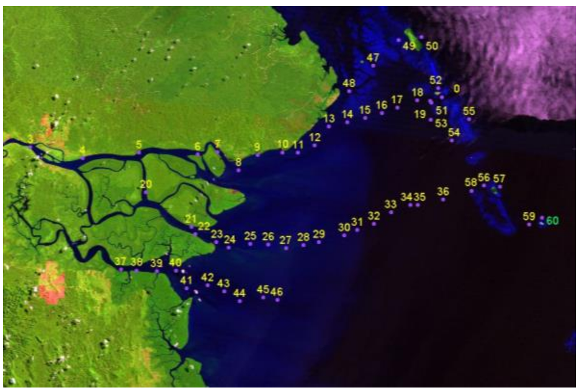


Figure 2-1. Location Observation

The initial steps were performed toimage corrected, ie geometric correction, radiometric correction and atmospheric correction (Ruddick 2008; Zhihua 2012; Nurandani 2013). The Landsat data with those several correction was named Landsat corrected data. The established TSS extraction algorithm was constructed empirically by finding correlation between TSS field data and Landsat corrected data (Parwati 2006, Lee 2011). The Corrected data was very important for this study because using Landsat time series data.

Data analysis was done by looking at the condition of TSS for each observed data. Evaluation of water quality was done partially on certain areas that have been studied, which was assumed to be a significant change of land use/land cover. Several regions were created for this study along the area. The land use/land cover dynamics directly affect the water conditions (Parwati 2006, Doxaran 2009, Sahu 2009, Larkin 2012 and Tadesse 2015).

In general the research stages are illustrated in Figure 2-2.

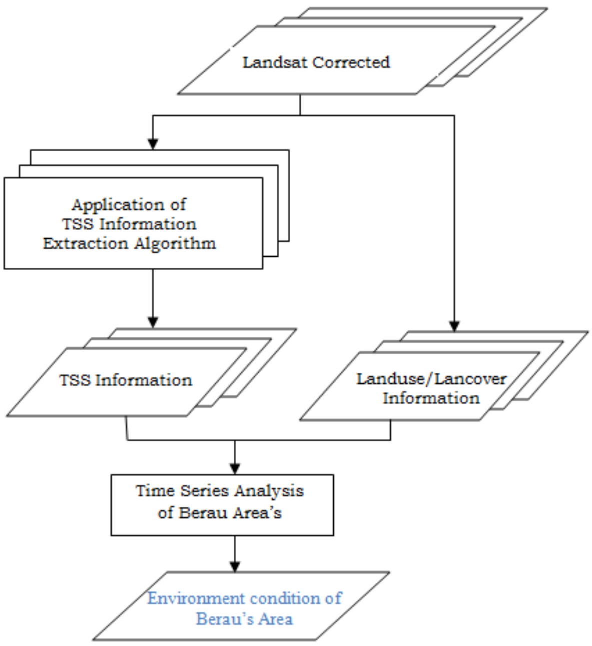


Figure 2-2. Flow Chart of Processing and Data Analysis

3 RESULTS AND DISCUSSION

3.1 Results

The validated TSS extraction algorithm was constructed by utilizing field data which has been collected. The image data used was adjusted to the time of field data collection which conducted in 2002, 2004 and 2006. The validated algorithm was used (Parwati 2006), as follow:

TSS (mg/l) = 0.6211 * (7.9038 * Exp (23.942 * Red Reflectance Band)) ^ 0.9645

This study was carried out by using all data collected, ie Landsat 5 TM and Landsat 7 ETM data obtained in 1994, 1996, 1998, 2002, 2004,2006 and 2008, and Landsat 8 data acquisition in 2013.

Evaluation of TSS extraction algorithm applied to all waters of study area from upstream to downstream. Figure 3-1 shows an example of the results of the application of the validated algorithm for the Berau waters in 2006. Blue degradation shows different TSS values for each point along the watershed to the coastal.

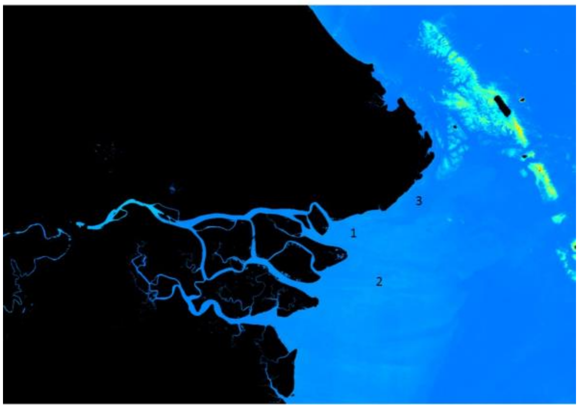


Figure 3-1. Application of TSS Algorithm Validated in Berau Waters

Visually, there was difference of blue degradation at each observation point taken. For example, the three points taken by the magnitude of each successive TSS value were: 1). 50.24 Mg/Lt, 2). 51.42 Mg/Lt and 3). 44.52 mg/Lt.

25 regions were stretched from the watershed to the ocean, where each region was taken when the land use change was

extreme. The conditions in several study sites, tropical regions, were often covered by clouds. Therefore, from 25 regions created, only 10 regions could be selected as the area to be evaluated (Figure 3-2).

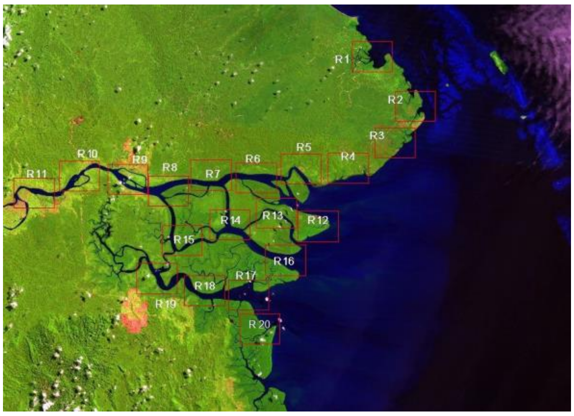


Figure 3-2. Selection of Berau River Region

Then, we selected four points which are relatively cloud-free points from each region for further analysis. A more detailed assessment of each developed regions was helpful in the analysis. For example, region 13, where the land cover conditions in the area are dominated by mangroves, ponds, bushes and bare land (Figure 3-3).

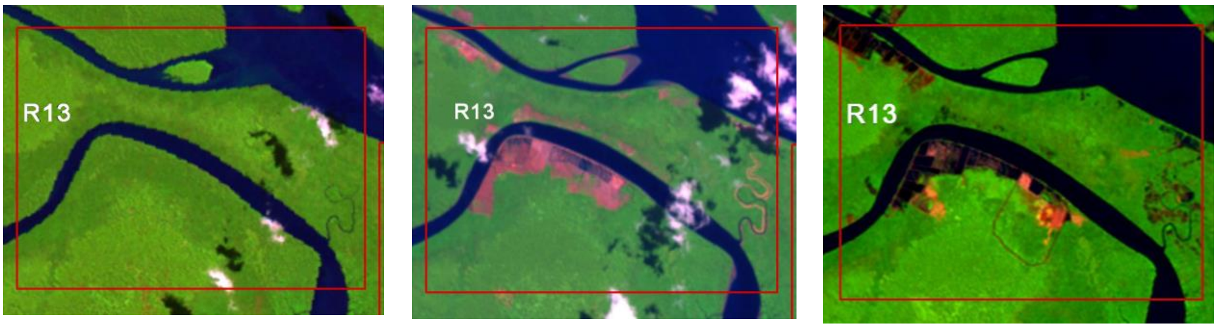
The land cover conditions around the selected area can illustrate the main caused of the dynamics occurring in the waters area seen from the fluctuation of its TSS value. Figure 3-3 describes the conditions of land cover change from 1994 to 2006. Meanwhile, figure 3-4 describe landuse landcover change from 1994, 2002 and 2006 in a whole area from watershed until ocean in Berau area.

The increasing of TSS concentration happen as a result of the opening of mangrove area into a pond. TSS value at point 10 in 2004 is 132.89 mg/l. But the study shows that the highest value of TSS is happen because the image is cloudy.

Although visually the points are taken are not covered by clouds, there will still be influence when the surrounding area is covered by clouds. This is reminded the researcher about the importance of selecting the data used to be cloud-free.

Table 3-1. TSS Data (Mg/Lt) in Region 13

Year	Point			
	7	8	9	10
2013	171.92	174.50	196.05	167.11
2008	114.96	118.29	120.12	122.07
2006	95.33	96.19	96.19	96.19
2004	119.77	113.71	92.39	132.19
2002	44.66	75.06	79.06	44.66
1998	58.92	75.04	54.35	63.87
1996	46.25	42.66	54.35	42.67
1994	46.25	42.66	42.66	46.25



1994 Condition 2002 Condition 2006 Condition

Figure 3-3. The Visual Condition of Landuse / Land Cover Changes in Region 13

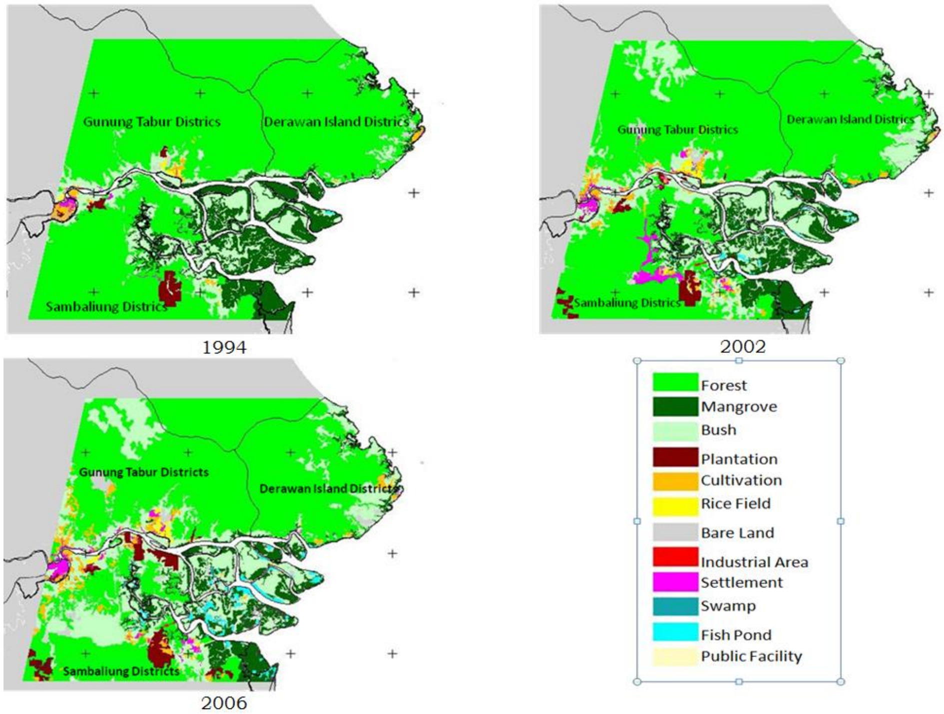


Figure 3-4. Landuse / Land Cover Change in Berau Area from 1994 until 2006

The application of validated TSS algorithm for Berau area can be showed visually in Figure 3-5 for 1994, 2002 and 2006 observed.

For analizing more detailed, the whole region chosen were analysed in his study. The TSS concentration in those 16 selected regions were consecutively presented in the graphs as shown in Figure 3-6, 3-7, 3-8, 3-9, 3-10, 3-11, 3-12, 3-13, 3-14 and Figure 3-15.

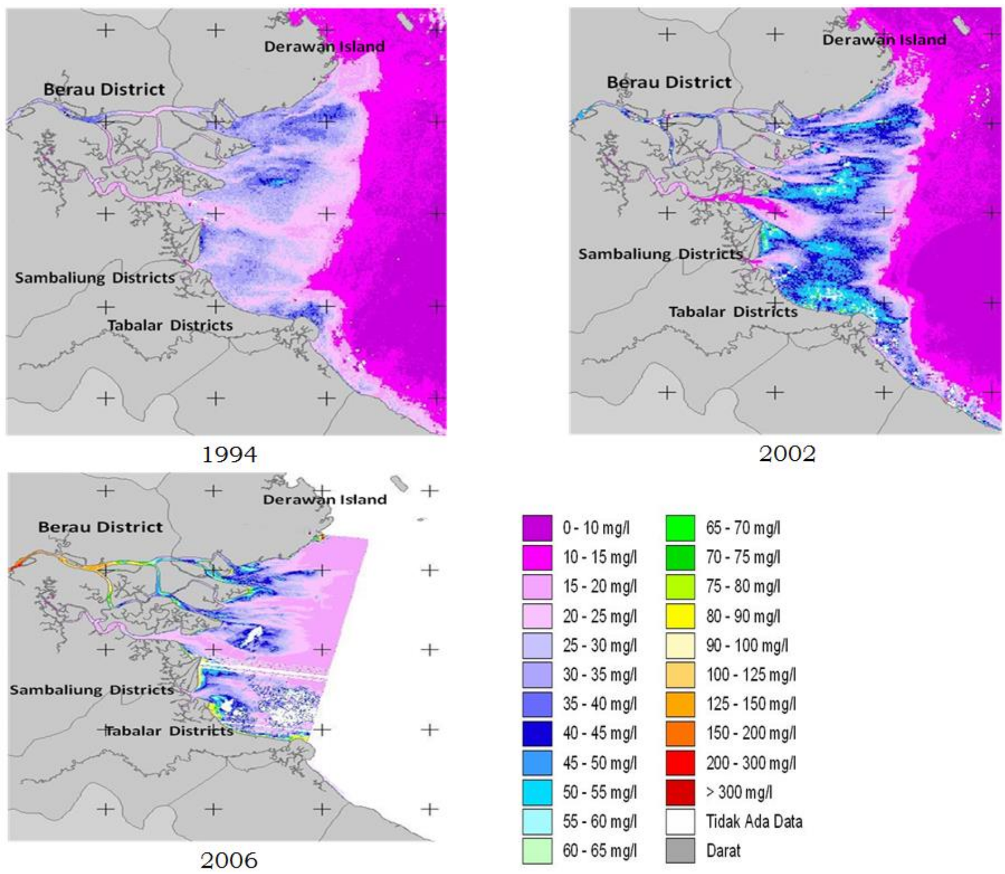


Figure 3-5. TSS Change in Berau Area form 1994 until 2006

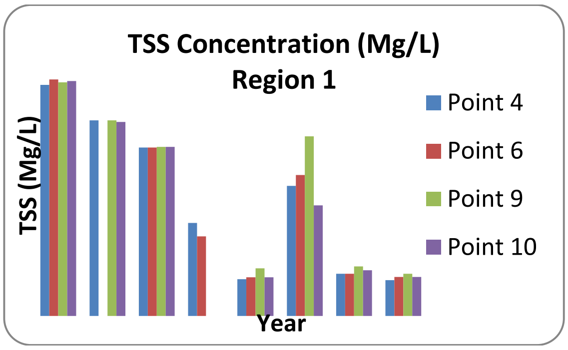


Figure 3-6. Graph of TSS Concentration Changes in Region 1

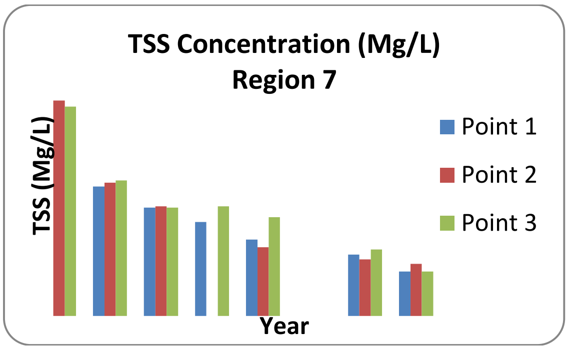


Figure 3-10. Graph of TSS Concentration Changes in Region 7

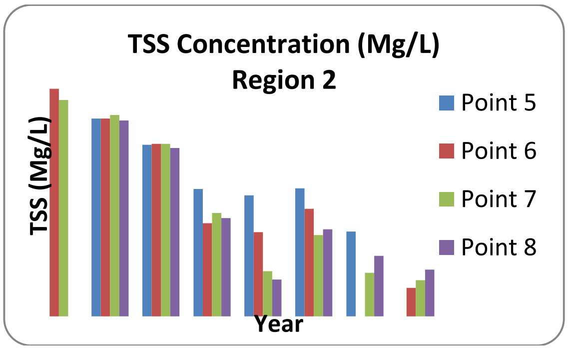


Figure 3-7. Graph of TSS Concentration Changes in Region 2

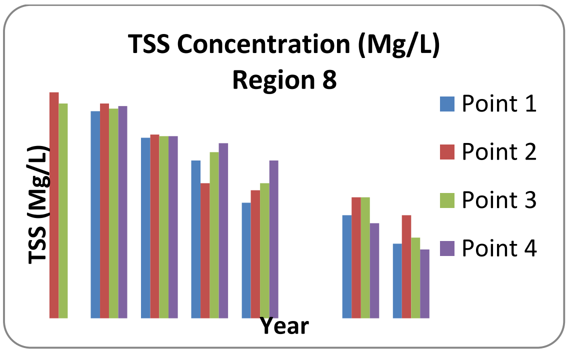


Figure 3-11. Graph of TSS Concentration Changes in Region 8

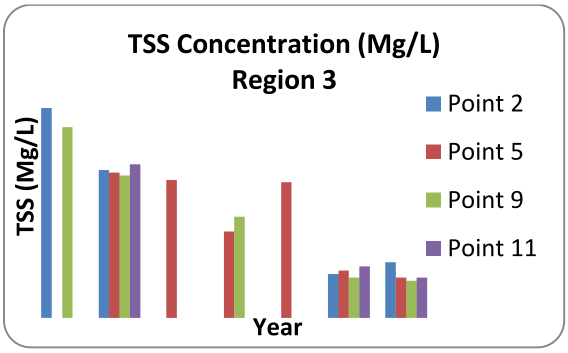


Figure 3-8. Graph of TSS Concentration Changes in Region 3

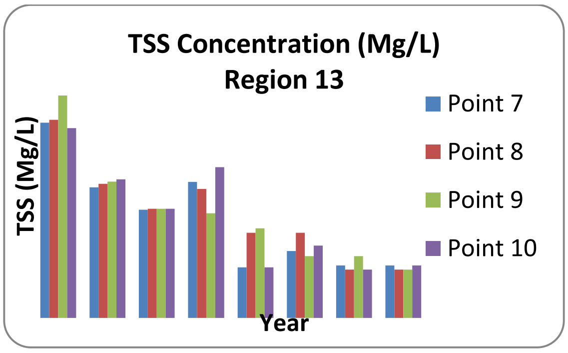


Figure 3-12. Graph of TSS Concentration Changes in Region 13

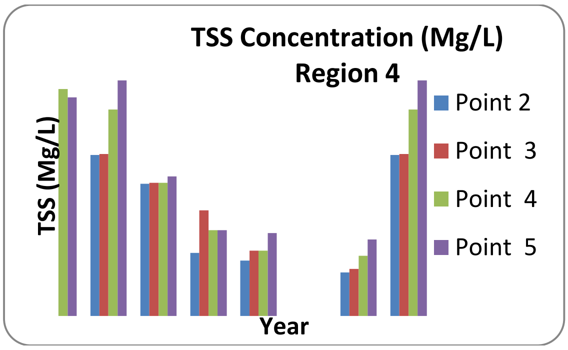


Figure 3-9. Graph of TSS Concentrations Changes in Region 4

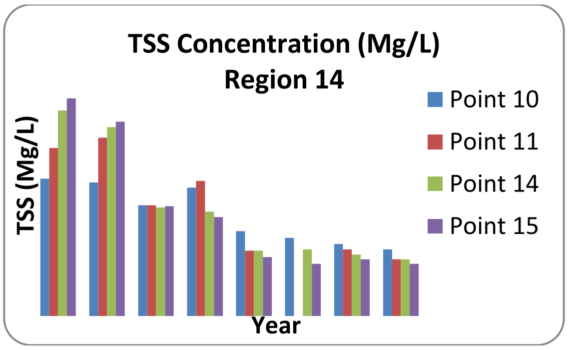


Figure 3-13. Graph of TSS Concentration Changes in Region 14

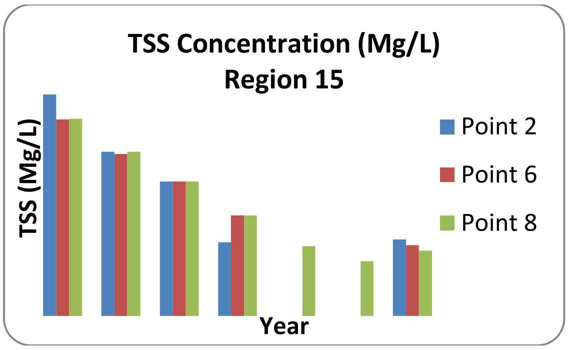


Figure 3-14. Graph of TSS Concentrations Changes in Region 15

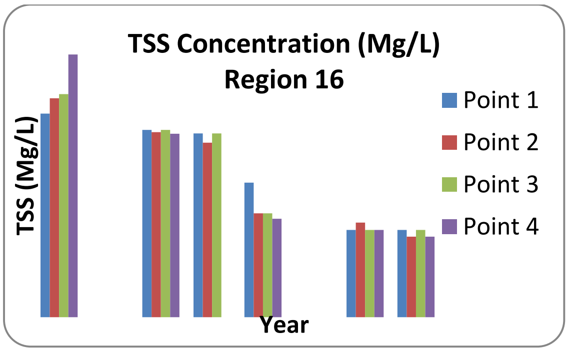


Figure 3-15. Graph of TSS Concentrations Changes in Region 16

3.2 Discussion

If special observations were made only in the conditions of 2008 and 2013 and the selected data were cloud-free, we could describe some of the conditions occurring in each region as follows.

In the region 1, the increase of TSS at point 4 is 15.38%, point 9 is 16.27% and point 10 is 17.41% and point 6 is cloudy. In the region 2, point 5 and point 8 are cloudy. The increase of TSS occurs at point 6 is 15.14% and point 7 is 7.41%. In the region 3, point 5 and point 11 are cloudy, the increase of TSS occurs at point 2 is 42.05% and point 9 is 34.00%. In the region 4, point 2 and point 3 are cloudy, whereas the increase of TSS occurs at point 4 is 9.97% and there is a decrease of TSS is 7.29% at point 5.

In the region 7, point 1 and point 4 are cloudy, while the increase of TSS occurs at point 2 is 61.58% and point 4 is 54.75%. In the region 8, point 1 and point 4 are cloudy, while the increase of TSS at point 2 is 5.18% and point 3 is 2.44%. In the region 13, points 7, 8, 9 and 10 had 49.55%, 47.52%, 63.21% and 36.90% respectively. In Region 14, the increase of TSS at points 10, 14 and 15 were respectively of 2.71%, 8.88% and 11.95%.

While the point 11 decreased about 5.81%. In Region 15, all points increased about 34.76%, 21.22%, 20.02% and 59.19% respectively . In region 16, the increase of TSS value in 2013 until 2008 can not be compared because the data is cloudy, while compared to 2006 data for Region 16 are: Point 1 (8.84%), point 2 (18.23%), point 3 (19.16%) and point 4 (43.26%).

Analysis on the relationship between land use change and TSS for Segara Anakan Lagoon area in Cilacap, Central Java in 2006 were done using remote multi-temporal Landsat remote sensing data obtained in 1978, 1998 and 2003. The results show that fluctuation of TSS value depending on land use change which has been done. The change to bareland is the cause of the highest increase of TSS value in the region (Parwati 2006).

Studies have also been conducted in the East Calcutta Wetland region of India (Sahu 2009). The result of the study was a specific policy planning for each zone. It looks at the conditions of land use change and the quality of the surrounding water. Studies for the Berau coastal areas show similarities in the two research activities that have been conducted. It was found that the change of land use that varies greatly on the upper land has caused from the sharpest rise found in Region 13 point 9 that is equal to 63.21%., The point 9 is in the meander position and is an open field area. The position of Region 13 is in the estuary which is dominated by pond. Changes in land use are very visible, mangrove conversion into ponds has increased significantly.

The points where the value of TSS is decreased, that is, point 5 in region 5 is 7.29%, it was known that the condition is facing directly with the high seas which automatically takes place the dilution process has occurred. Another point was point 11 in region 14, TSS decline of 5.81% is an area with better mangrove conditions. As very clearly known, mangrove was one of the good pollutant absorber.

These results also strengthen or confirmed by previous studies that have been conducted, including those on river ecosystems (Larkin 2012). Those researches itself were conducted along the river to the estuary where in the area encountered the development of fishery industry area, consequently the condition of the waters have a significant increase TSS.

4 CONCLUSION

Landsat multi-temporal data can be used to evaluate the condition of the observation region. Selection of cloud-free image data becomes the main requirement for the evaluation results to be done has a high accuracy value.

Berau waters condition is very dynamic. Therefore the increase and decrease of TSS experienced could linearly describe activity that happened at observed area.

The results of this study show that any activity in the upper land will have a consequence on the water conditions in the area indicated by the increase and decrease of the TSS value. The addition of mangrove areas at several locations was followed by a significant decrease in TSS value. Therefore, reforestation or rehabilitation of mangrove areas can be used as one of the selected alternatives to increase the value of TSS can be reduced.

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